Agriculture, Climate Change, and Soil Carbon

Agriculture and forestry account for some 22% of global greenhouse gas emissions.[9] The most direct way that the agricultural sector can help fight climate change is by lowering its carbon footprint via practices such as raising fewer livestock in factory farm conditions, reducing use of synthetic fertilizers and pesticides, and preventing the conversion of existing biodiverse, carbon-rich ecosystems, such as forests, into farmland to begin with. But the focus of most agriculture carbon-credit programs, and thus the focus of this report, is on farmers' ability to sequester carbon in soil.

How farmers treat their soil has significant climate implications given that farmers and ranchers manage more than half of the U.S. land base.[10] Investments in supporting farmers to transition to more biodiverse, agroecological, and perennial farming methods could help sequester more carbon in the soil, reduce reliance on synthetic fertilizers and pesticides, and make farms more resilient in the face of climate change. However, most carbon-offset programs focus on promoting cover-cropping and reduced tillage along with otherwise chemical-dependent and monoculture farming practices. These methods are not as effective for sequestering carbon and introduce other environmental harms.

SOIL AS A LIVING SYSTEM

Earth's soils contain more carbon than all its biomass and atmosphere, combined.[11] The life of soil is at the heart of its ability to capture and store carbon. Plants take in carbon from the air and use it as the basis for plant matter. This carbon is released through roots into the soil thanks to a teeming ecosystem of microorganisms. Invertebrates such as earthworms and springtails also feed on fallen plants, breaking them down and excreting carbon-rich casts and feces, mixing organic matter into the soil as they go.[12]

Thus, one key component of truly regenerative farming systems is that they protect and enhance soil biodiversity. Research shows that the pesticides commonly used in U.S. agriculture pose a serious threat to soil organisms.[13] A recent meta-review found that pesticides kill or harm soil invertebrates in 71% of cases studied.[14] This makes it very concerning that some of the largest players in the establishment of soil carbon markets are pesticide companies like Bayer and Corteva.

Additionally, soil carbon is just one indicator of the health of agricultural ecosystems and is difficult to accurately measure compared to others. Other measures such as soil biodiversity and water filtration can give a more holistic picture of soil health. Focusing only on carbon could incentivize a reductionist approach to carbon farming, further entrenching unsustainable, chemical-intensive industrial agriculture practices.

REGENERATIVE FARMING APPROACHES

Practices such as cover-cropping, crop diversification, agroforestry, and applying compost can be part of holistic regenerative farming systems. Data on organic farming — which depends on ecological methods to build soil health and control pests, and which prohibits the use of over 900 agricultural pesticides — demonstrates that these methods can improve soil carbon sequestration. Organic farms have been found to sequester up to 25 percent more carbon in the soil[15] and achieve deeper and more persistent carbon storage[16] than farms using agrichemical approaches.

Biodiverse farming and ranching systems that incorporate trees, shrubs, and perennial plants also have greater potential to sequester carbon than annual cropping systems. One study estimated that adopting agroforestry on just 10% of U.S. crop and grazing lands could sequester enough carbon to offset up to 30% of all U.S. annual carbon emissions.[17] Another study found that, even by conservative estimates, agroforestry can sequester 10 to 20 times more carbon per acre than practices such as no-till or cover-cropping.[18]

A REDUCTIONIST APPROACH TO CARBON FARMING

Despite the available data demonstrating that diverse and agroecological farming systems have the greatest potential to sequester carbon, most agricultural carbon-credit programs promote practices that are compatible with monoculture annual crop production, including no-till farming and cover-cropping.

While some data show the potential for no-till agriculture to improve soil carbon sequestration,[19] the latest data show that no-till may actually redistribute soil carbon from the deeper layers into the top layers of soil rather than increase soil carbon stocks.[20] This effect could cause more carbon release from soil rather than storing it deep in the ground where it is more stable — particularly as intermittent tillage may be important in no-till systems in some regions.[21]

One meta-study looking at 69 experiments around the globe found no significant difference in soil carbon levels between conventionally tilled and no-till fields when studies measured the deeper layers of soil.[22] Some studies examining carbon at deeper soil depths also cast doubt on the ability of cover crops alone to sequester carbon. Using multiple practices together may improve outcomes; for example, one study found that cover-cropping combined with no-till may sequester more soil carbon than released in the long term.[23]

THE CHALLENGE OF MEASURING SOIL CARBON

While it is evident that some farming practices have more carbon-sequestering potential than others, the science of agricultural soil carbon sequestration is complex and developing. There isn't a clear consensus on how long carbon remains in the soil or under what conditions.[24] Disturbing soil and changing weather can release years of stored soil carbon into the atmosphere.[25] There are major uncertainties around measuring year-to-year changes in soil carbon, the very type of measurements needed to make annual payments to farmers for implementing practices such as cover-cropping or no-till farming.[26] Other studies suggest that soil may reach a carbon saturation point past which no more carbon can be stored.[27]

Soil carbon sequestration also varies considerably by soil type and climate and can even vary significantly within a single field.[28] One study found that soil carbon concentrations can vary fivefold in a seemingly uniform field.[29] The tools required to measure soil carbon to the degree of accuracy needed to ensure integrity in a carbon market do not exist.[30] Without adequate measurement tools, farmers and carbon-offset sellers can't actually determine how many tons of carbon their credits represent.

The tools required to measure soil carbon to the degree of accuracy needed to ensure integrity in a carbon market do not exist.

With so much uncertainty and variability in measuring and modeling soil carbon sequestration, programs that aim to quantify and commoditize farmers' total tons of sequestered carbon are largely based on assumptions and projections rather than actual measurements.
In addition, new understandings of how microorganisms

break down soil carbon suggest that many computer carbon models, including those used to estimate carbon sequestration for carbon credits, overestimate how much carbon will stay in the soil.[31]

All of these challenges create fundamental issues when carbon payment programs try to turn farmers' sequestered carbon projections into sellable offset credits in carbon markets. If buyers can't trust that any given carbon credit represents the tons of offset carbon that it claims to, how can they assign it a value and price?

If buyers can't trust that any given carbon credit represents the tons of offset carbon that it claims to, how can they assign it a value and price?